Int. Adv. Otol. 2011; 7:(1) 82-86

ORIGINAL ARTICLE

# Relationship Between Bone Conduction Thresholds and Hearing Results After ear Surgery

**Maciej Wiatr, Jacek Skladzien, Jerzy Tomik, Krzysztof Oles, Pawel Strek, Anna Przeklasa-Muszynska**

*Otolaryngology and Otolaryngological Clinic at the Collegium Medicum of the Jagiellonian University of Krakow*

**Objective:** The authors investigated the link between an increase in perceptive hearing loss and the effectiveness of tympanoplasty operations

**Materials and methods:** A prospective analysis of patients operated on for the first time for management of chronic otitis media was performed. A total of 147 patients operated on between 2004 and 2007 met the criteria.

**Results:** The study population was divided into three groups according to their preoperative bone conduction thresholds (averages of 500 Hz, 1 000 Hz and 2 000 Hz). A considerable improvement in hearing quality was observed as early as 6 months after surgery in the group with normal bone conduction. An improvement was also observed for patients with bone conduction values oscillating between 21 and 40 dB, though only after longer periods of observation (12 months). Increased perceptive hearing loss (>40 dB) coincided with the absence of considerable hearing improvement after otosurgery.

**Conclusion:** Severe perceptive hearing loss is an unfavourable prognostic factor for hearing improvement in patients with chronic otitis media undergoing otosurgery.

*Submitted : 11 September 2009* *Revised: 04 August 2010* *Accepted : 24 August 2010*

## Introduction

Many authors have focused on finding the effects of the sound conduction system of the middle ear with the function of the inner ear [1, 2, 3, 4].

Significant observations were made on hearing loss mechanisms in regard to the middle ear problems such as advanced cholesteatoma, mucosal changes or ossicular chain damage. These pathologic changes seem to indirectly distort the inner ear function. An example of this phenomenon is the loss of bone conduction threshold in response to ankylosis of the stapes as a result of otosclerosis that was described by Carhart in 1958 [5, 6, 7].

The toxic effects of the inflammatory lesions in the middle ear can also impair the inner ear functions. This process may induce the biochemical changes in the perilymph and the endolymph by acting through the round window. These mechanical and biochemical factors often act simultaneously. It is believed that the bone conduction impairment in the process of chronic otitis media can be induced either by chronic inflammatory process or an iatrogenic insult caused by manipulation of the ossicular chain. Additionally the noise induced by drilling can also damage hearing [8, 9].

The aim of the research was to assess the relationship between preoperative bone conduction and the outcomes of otosurgery, expressed as a decrease in the air-bone gap (ABG).

## Material and Methods

Between the years 2004-2007, 457 patients underwent ear surgery in the Department of Otolaryngology at the Jagiellonian University of Krakow. The analysis

**Corresponding address:**
Maciej Wiatr, M.D.
Poland Krakow ul. Sniadeckich 2
Phone: 00 48 12 424 79 00 • Fax: 00 48 12 424 79 25
E-mail: mwiatr@mp.pl

included patients undergoing an operation for the treatment of chronic otitis media. The patients described in this paper are those who underwent ear surgery for the first time. A total of 147 consecutive patients met the criteria for inclusion in the study. The youngest patient in the group was 6 years old, while the oldest was 80 years old. The average age of the patients was 40.84 years. The study included 80 women and 67 men.

Each of the patients gave informed consent to take part in the studies conducted for the purpose of this paper.

The nature of the study was the prospective analysis of patients operated on for the first time for management of chronic otitis media. When gathering the data, the researchers prepared a questionnaire to assess characteristics of the study subjects, the diagnostic procedures, the surgical methods and the hearing acuity control during direct and remote postoperative hearing level tests.

The study involved changes in the ABG (averages of 500 Hz, 1,000 Hz and 2,000 Hz), depending on the primary values of bone conduction. The assessment was based on audiometric tests carried out directly during the preoperative period, as well as 6 and 12 months after ear surgery.

The patients were assessed in three groups based on the average bone conduction values (500 Hz, 1 000 Hz and 2 000 Hz) measured prior to surgical intervention (Table 1).

**Table 1.** Groups of patients subdivided according to the primary bone conduction thresholds

| Groups (based on bone conduction thresholds) | The average of the original bone conduction values (dB) |
|---|---|
| 1 | 0 – 20 |
| 2 | 21 – 40 |
| 3 | ≥ 41 |

The first test attempted to analyse improvements in hearing was the Fisher test. The test used to verify non-parametric hypotheses was the multi-field contingency tables test (a.k.a. the $\chi^2$ test). Pearson's chi-square test was used to calculate $\chi^2$, and it was confirmed with the use of the maximum credibility chi-square test. Results were considered statistically significant when the p-value was < 0.05.

## Results

The analysis involved 147 consecutive patients with chronic otitis media who underwent ear surgery for the first time in the discussed time span.

Middle ear mucosa changes were observed in 123 patients. Isolated fibro-adhesions, isolated granulation and granulation coexistent with cholesteatoma or fibro-adhesions were usually observed.

During otosurgery, erosion of the ossicular chain was observed in 78 patients. The most frequent defects were of the incus. Destruction to the malleus and incus or total lack of ossicular chain were less frequent. No defect to the malleus and stapes in the same time was observed.

For the majority of patients, reconstruction of the sound conduction system of the middle ear included ossiculoplasties.. Myringoplasty was performed in 44% of individuals, but only 16% of them have no mucous changes.

In all analyzed groups average ABGs before treatment were comparable (28-30dB). Range of changes of the mucous membrane and damage of the ossicular chain determined postoperative ABG closure.

It was observed that the average ABG in the established groups of bone conduction assumed the following values (Table 2)

Based on the data obtained, it was concluded that 6 months following otosurgery, the change to the average ABGs for the established groups was statistically significant ($p<0.05$). The average for group 1 differed significantly from the averages for groups 2 and 3, and the difference between the average ABGs for groups 2 and 3 after 6 months of observations was statistically insignificant. This means that there was a substantial improvement of hearing and a decreased ABG in the primary bone conduction threshold for group 1, as compared to groups 2 and 3. When analyzing the average ABG between groups 2 and 3, no statistically significant changes were diagnosed after 6 months of observation.

Similar to the control conducted 6 months after the operations, it was observed 12 months following surgery that the average ABG in group 1 was substantially lower than the corresponding average ABGs in groups 2 and 3 ($p<0.05$). On the other hand, the average ABGs for groups 2 and 3 were not significantly different.

The results observed 12 months following surgery confirmed the continued improvement in the hearing of group 1, which was also observed 6 months after surgery. No statistically significant changes to the average ABG between groups 2 and 3 were observed.

The next stage involved analyzing changes in the average ABGs observed during the consequent follow-ups within each of the primary bone conduction groups (Table 3).

The patients with normal bone conduction (up to 20 dB) were diagnosed with an improvement in their hearing and was expressed by an average ABG observed after 6 months. This average was maintained after 12 months post-operatively. The results were statistically significant ($p<0.05$).

In group 2, a statistically significant hearing improvement was observed one year after surgery. The average ABGs during early treatment and 6 months after surgery did not differ significantly. The results 6 and 12 months after the surgery were statistically equal as well. In group 3, no statistically significant improvement in hearing was observed after 6 and 12 post-operatively ($p>0.05$).

**Table 2.** Average ABG in bone conduction threshold groups at the beginning of treatment and after 6 and 12 months of observations.

| bone conduction groups | X 0 | SD 0 | X 6 | SD 6 | X 12 | SD 12 |
|---|---|---|---|---|---|---|
| 1 | 28.47 | 12.15 | 21.30 | 10.06 | 19.28 | 12.24 |
| 2 | 30.60 | 12.56 | 26.49 | 11.84 | 25.30 | 12.01 |
| 3 | 28.38 | 10.76 | 26.66 | 9.84 | 28.25 | 12.16 |

*(X= average ABG; X 0= average ABG prior to treatment; X 6= average ABG after 6 months of observations; X 12= average ABG after 12 months of observations; SD= standard deviation)*

**Table 3.** Changes in the average ABGs over time within the established groups based on bone conduction

| Time (months) | X bone 1 | SD bone 1 | X bone 2 | SD bone 2 | X bone 3 | SD bone 3 |
|---|---|---|---|---|---|---|
| 0 | 28.47 | 12.15 | 30.60 | 12.56 | 28.38 | 10.76 |
| 6 | 21.30 | 10.06 | 26.49 | 11.84 | 26.66 | 9.84 |
| 12 | 19.28 | 12.24 | 25.30 | 12.01 | 28.25 | 12.16 |

*(X bone i = the average ABG in bone conduction group i, where i stands for the number of the analysed group (1-3);*
*SD bone i = standard deviation in bone conduction group i, where i stands for the number of the analysed group (1-3))*

## Discussion

Having taken into account that the general effectiveness of otosurgery depends on the bone conduction value, it was concluded that a substantial hearing improvement was seen in the group with normal bone conduction as early as 6 months after the surgery. An improvement was also observed in patients with bone conduction values oscillating between 21 and 40 dB, but this was only the case after a longer observation period of 12 months. A more severe perceptive hearing loss (≥41dB) coincided with a lack of substantial improvement in hearing after otosurgery. This conclusion is innovative and highly significant for practical reasons, since it questions the utility of surgical treatment for improving the quality of hearing in patients with perceptive hearing loss. Otosurgery should be aimed at removing a pathogenic process, such as a cholesteatoma, or separating the region of the middle ear from unfavorable effects of the external environment by sealing a damaged tympanic membrane. In addition, the use of a hearing aid or BAHA after surgery should be considered for restoration of normal ear biology.

In the first group changes observed in the middle ear enabled complete removal of mucous abnormalities and then reconstruction of the tympanic membrane and ossicular chain with good distant result. In these patients the most often type I and II tympanoplasty was performed.

In some patients mucous changes (scars, cholesteatoma, granulation) were localized in the region of the round window. Their removal leads to significant hearing improvement.

In the 3rd group two different populations of individuals can be distinguished.

The first one with intact ossicular chain, no mucous membrane changes and small ear drum perforation. In these patients ABGs changes were insignificant.

The second, larger group had advanced mucous abnormalities (granulation, cholesteatoma) with severe destruction of the ossicular chain (damage of stapes superstructure was often observed). Tympanoplasty with significant hearing improvement was very difficult to obtain in these patients.

There is a long-standing debate on the impact of middle ear surgery on the functionality of the inner ear. Vartiainen et al. concluded that 92% of a total of 181 patients who underwent surgery for the treatment of chronic otitis media did not experience changes in their bone conduction threshold post-operatively. In contrast, 5% saw an improvement, while the remaining 3% were diagnosed with a decrease in bone conduction. An improvement within the range of 11-25 dB was observed after the elimination of advanced pathogenic changes of the tympanic cavity. On average, an improvement in bone conduction is observed in nearly 10% of the patients operated on for chronic inflammatory changes of the middle ear [1, 2, 3, 10].

Many researchers have sought a link between pathogenic processes in the middle ear and their effects on the inner ear, as expressed by an increase in the bone conduction threshold. Numerous analyses have proven a definite existence of such interdependency [2, 3]. Significant observations were made with regard to changes in the middle ear, such as advanced cholesteatoma, mucous changes or ossicular chain damage. Via their effect on the mechanics of the ossicular chain, these pathologic factors seem to indirectly distort the function of the inner ear. An example of this phenomenon is the increased bone conduction threshold in response to ankylosis of the stapes as a result of otosclerosis that was described by Carhart in 1958 [5, 6, 7].

Another way of explaining bone conduction disturbances is to blame the toxic effects of the inflammatory process of the middle ear on the function of the inner ear. The possibility has also been proposed that biochemical changes in the perilymph and the endolymph due to the effects of substances from the middle ear penetrating the round window may play a role. The mechanical and biochemical factors referred to above often act simultaneously. It is believed that the bone conduction impairment in the process of chronic otitis media can be induced either by chronic inflammatory process or an iatrogenic insult caused by manipulation of the ossicular chain. In addition, the noise produced when drilling the temporal bone may be to blame [8, 9].

Linstrom et al. did not observe any substantial improvement in bone conduction thresholds in patients whose ossicular chains were not reconstructed during middle ear surgery [11]. Statistically significant improvement was observed in patients subjected to ossiculoplasty. This observation confirms the theory that reconstruction of the ossicular chain has a beneficial effect on the level of bone conduction. Middle ear surgery restores the influence of the middle ear on the function of the inner ear that was previously disturbed by the inflammatory process in the tympanic cavity. It seems that pathogenic changes to the mucous of the middle ear may disturb the restoration of complete interdependency of the bone conduction threshold and the ossicular chain.

Another argument that confirms the effect of the mechanics of the ossicular chain on bone conduction threshold is the major improvement in the threshold values for 2,000 Hz observed in patients with reduced ABGs for 500, 1,000, 2,000 and 4,000 Hz. Tonndorf claims that the most severe disturbance of bone conduction values for 2,000 Hz results from decreasing or eliminating ossicular resonance. For humans, the ossicular resonance oscillates between 1,500 and 2,000 Hz. The above effect is observed with regard to the conditions involving the ossicles [11].

## Conclusions

1. Severe perceptive hearing loss can be detrimental to hearing improvement in patients with chronic otitis media.
2. When operating on patients with the most severe damage to the ossicular chain and in whom the bone conduction threshold points to a substantial functional disorder of the inner ear (i.e. a small ABG), the decision to pursue surgery aimed at improving hearing should be made carefully, although ear biology restoration should be still be pursued.
3. Damage to the ossicular chain and extensive changes in the mucous lining the middle ear can be taken into consideration as the factors that inhibit reduction of the ABG and the restoration of the beneficial effects of the mechanics of the middle ear on the function of the inner ear.
4. The priority in treating chronic otitis media should be the elimination of inflammatory changes, obtaining a “dry ear” and restoring the anatomical relations in the region of the middle ear that will eventually allow hearing improvement with the use of a hearing aid.

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